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13. ABSTRACT *(Maximum 200 words)*

This final report summarizes research activities of AASERT-supported students during the period June 1, 1992 to June 30 1996 under contract #F49620-92-J-0337. Key accomplishments included: 1. generation of intense THz radiation by triggering vertical Gunn diodes with optical pulses; 2. construction of a new tunable femtosecond regenerative amplifier system; 3. generating tunable narrowband Thz radiation in free space from photoconducting antennas; and 4. fabricating oxide superconducting electronic devices using ion implantation patterning.

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SUMMARY OF RESEARCH

Students supported by AASERT Contract F49620-92-J-0337 included Julia Soltz (M. S., 1994), Jason Miller (M. S., 1996) and Franklyn Farrell. Interdisciplinary training in applied physics and electrical engineering was provided; research related seminars and courses were available; and the students participated in the research of generation of application of intense terahertz EM radiation from photovoltaic devices which was supported by the parent contract, AFOSR #F49620-92-J-0036. Accomplishments for the period 1992 - 1996 included:

1. Generation of intense THz radiation by triggering vertical Gunn diodes with optical pulses A new method was developed which enabled us to generate intense bursts of electrical oscillations in the THz region of the electromagnetic spectrum. Our new method was based on the idea of triggering Gunn oscillation in a vertical Gunn diode with a femtosecond optical pulse. We designed a vertical transferred electron device (TED), e.g. a Gunn diode, with an intrinsic buffer layer between the active region and the cathode. The speed of a Gunn diode itself was normally determined by the length of the active region, and the upper limit was intrinsically set by the time carriers need to transfer from the L valley to the G valley which has been measured recently to be about 2 ps. Initially, the vertical device was biased in such a way that the field in the active region was slightly below the threshold for Gunn oscillations to start. By properly choosing an appropriate femtosecond optical excitation source, we could inject a large number of photocarriers within the buffer layer. Therefore, the field of the active region was quickly switched above the threshold field, causing a burst of electrical oscillation. The duration of the oscillation was determined by the time required by photocarriers to sweep the buffer region, the carrier recombination time, etc.. The detection of the electrical burst was achieved by measuring the radiation in the free space using a photoconductive dipole antenna. The detected radiated signal was composed of two contributions: the broadband signal caused by the fast initial rise of the photocurrent in the buffer region; and the narrow band oscillatory contribution due to the Gunn effect in the active region. When the bias field was much higher than the threshold, no Gunn oscillation was observed, while in the case where the field is close to the threshold voltage, an oscillation was observed.

2. Construction of a new tunable femtosecond regenerative amplifier system: Construction of the tunable femtosecond regenerative amplifier system was completed. We needed to have an optical source which could deliver a few hundred micro-joule or even a few milli-joule femtosecond optical pulses with kiloHertz rep rate. A regenerative amplifier system, designed by Salin et al. at the University of Michigan, was best suited for our purpose. This system was based on the idea of chirped pulse amplification, i.e., the optical pulse was first stretched in time to avoid gain saturation, and then recompressed down after amplification. It

consists of a Ti: sapphire oscillator, a Q-switched YLF laser, a pulse stretcher, a regenerative amplifier cavity, and a pulse compressor.

3. Generating tunable narrowband Thz radiation in free space from photoconducting antennas: We demonstrated a simple scheme of generating tunable narrowband Thz radiation in free space from photoconducting antennas. This scheme uses the quasi-sinusoidal optical modulation at tunable Thz frequencies produced by beating two linearly chirped broadband optical pulses with a variable delay in a Michelson interferometer. The center frequency of the Thz produced by such optical mixing can be tuned out to the optical bandwidth available (~ 3.5 Thz) by varying the delay between the chirped pulses. The bandwidth of this narrowband Thz is proportional to the ratio of the initial to the final stretched pulsewidth and can be as low as ~ 5 Ghz. We also constructed a novel tunable optoelectronic Thz beam system for time-domain far-infrared spectroscopy composed of a narrowband tunable photoconducting dipole emitter and a synchronously gated tunable dipole detector which coherently measures th Thz field.

In order to generate intense Thz radiation, we built a high optical fluence source of femtosecond pulses. Our Ti:sapphire regenerative amplifier system, based on the design of Salin *et al.* of the University of Michigan, is capable of generating 0.5 to 1.0 mJ, 100 fs pulses at 800 nm with a 1 kHz repetition rate when pumped with a frequency-doubled Q-switched Nd:YLF laser. There are several projects which were pursued with this system: 1) generation of intense Thz radiation from a variety of new non-linear optical materials such as poled polymers; 2) generation of tunable narrowband Thz in free space as described above; and 3) non-linear optics in the far-infrared.

We demonstrated a new Thz generation technique that allowed us to generate intense bursts of electrical oscillations in the sub-millimeter wave region o the electromagnetic spectrum. This method was based upon the idea of triggering Gunn oscillations in the active region of a vertical transferred electron device such as a Gunn diode with an intense femtosecond optical pulse. By injecting a large number of photocarriers within the intrinsic buffer layer, the field in the appropriately biased active region was quickly switched above the threshold field, causing a burst of electrical oscillations. The duration of these oscillations was determined by the photocarrier sweep out rate, the carrier recombination time, etc. The electrical burst was coherently detected by measuring the Thz radiation emitted using a gated photoconducting dipole antenna. The detected signal was composed of two contributions--the broadband signal caused by the fast initial rise of the photocurrent in the buffer region, and the narrowband oscillatory contribution due to the Gunn effect in the active region.

4. Fabricating oxide superconducting electronic devices using ion implantation patterning: A new method of fabricating oxide superconducting electronic devices using ion implantation patterning was developed. The method is particularly attractive to

the making of superconducting transmission line and millimeter-wave device structures. Simple testing device structures were made on YBaCuO film with Al and Si implantation through a photoresist mask. The material properties of the implanted films were studied. The unique feature of the implantation method permitted us to make high-speed optoelectronic components based on semiconductor-superconductor hybrid structures. We also pursued the measurements of the propagation of the picosecond electrical pulses on the superconducting transmission lines by optoelectronic sampling techniques.

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